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Sent by fax

Dear Sirs

International Patent Application No. PCT/GB2004/001846
MASS CONSULTANTS
Our ref: MASEB/P30636PC

Further to the Written Opinion dated 23 February 2005, we hereby file replacement pages 45 to 54 to replace those corresponding pages as presently on file.

Also attached is a document entitled Remarks which sets out the distinctions of the present invention over the cited prior art.

It is considered that the application is novel and inventive over the cited prior art.

Yours faithfully
ERIC POTTER CLARKSON

Nicholas VH Fox-Male vc

Enc: Replacement pages 45 to 54
Remarks

REMARKS

Independent Claims 1 and 32 have been amended by replacing the phrase "with body directional control", with the phrase "with control to a predetermined angle of attack".

Support for this amendment is provide throughout the specific description for example at page 3 line 17 to page 4 line 1, page 7 lines 14 to 18, page 22 line 10 to page 27 line 3, but especially page 42 lines 8 to 12, the latter passage stating:-

> "At any point in the trajectory, control to achieve an implied $\alpha = \alpha_0$ (i.e. appropriate ZLL) since the sightline angle γ_{sl} minus this angle is constant at the same point, (it) opens the possibility of varying a demand ZLL to achieve a favourable look angle to the target while ensuring manoeuvre potential below the stall."

These Claims 1 and 32 as amended are clearly distinguished over all the cited prior art by the following features:

- A control system having continuous variable displacement throughout flight for manoeuvre of the main body relative to the flight path velocity vector;
- A control system which provides angle-of-attack control parameters additional to merely the manoeuvre control parameters of conventional systems.

Thus D1, being US Reissue Patent 37331, discloses a control system which provides a control routine as described in column 4 lines 31 to 58 only for a very short period, namely in the early stages of manoeuvre. Thereafter, and for the whole of the rest of the flight, no such control routine is used and the control operation defaults to standard control routines, see column 5 lines 37 and 38 which states:

> "After this initial movement, the fins are deflected in a direction conventional for the maneuver."

Furthermore, at no stage in the flight, whether during the above manoeuvre stage or at any other time, is there any control to the angle-of-attack function, as now claimed in Claim 1.

D2, being European Patent No. 0 747 655, discloses an auto-pilot blending control operation at page 6 lines 31 to 54 which again only provides control for the manoeuvre step, thereafter reverting to the standard routines, as explained on page 5 line 35-36:

> "The thrust level returns to zero (third graph) and the thrusters 15 are available for further manoeuvres."

And on page 7 lines 4 and 5:

"canard angle deflections are returned to zero (third graph) and the canards 14 are available for further manoeuvres".

D3, being US Patent Specification No. 4,598,888, does not disclose continuous variable displacement in flight, and the disclosure at column 4 lines 42 to 47 of "optimal angle of attack" would be understood by the appropriate skilled person to mean.....(that for a manned aircraft?).

Finally D4, being US Patent Specification No. 3,754,432 does not disclose control of continuous variable displacement in flight, nor control to a predetermined angle of attack.

The present invention as now claimed provides the control of a craft such as to ensure optimised and enhanced look to the target throughout the flight. This allows improved accuracy onto the target and in particular the ability to strike the target with zero grazing incidence or some predetermined grazing incidence for maximum warhead effectiveness. Control of body angle of attack and attitude during flight also enables reduction in radar cross section when approaching a target thereby offering improved stealth. The new method of control also provides the option to reduce time to target intercept with more efficient use of the method of propulsion and most importantly (when compared with the prior art) enables rapid response divert capability as a continuous inherent feature as opposed to intermittent discrete feature upon demand.

CLAIMS

1. A control system for a craft having two wing control surfaces spaced apart along a main body section of the craft, the system comprising automated synchronized operation of the two wing control surfaces for continuous variable displacement in flight for manoeuvre of the main body relative to the flight path velocity vector with control to a predetermined angle of attack.

2. A control system according to Claim 1, comprising automated synchronized operation of the two wing control surfaces for continuous variable displacement in flight for manoeuvre of the main body relative to the flight path velocity vector with control to a predetermined angle of attack and attitude relationship.

3. A control system for a craft according to Claim 1 or 2 comprising means for automated synchronized operation of the two wing control surfaces to maintain continuous variable displacement of each wing control surface via independent actuation under the action of a control routine.

4. A control system for a craft according to any preceding claim comprising means for independent actuation of both wings under a control routine involving a soft actuation mechanism.

5. A control system for a craft according to any preceding claim comprising means for a demand manoeuvre to act along an axis normal to a Zero Lift Line and in the plane of manoeuvre.

6. A control system for a craft according to Claim 5 wherein the Zero Lift Line is that line co-incident with the local wind axis velocity vector,

acting in the plane of manoeuvre in which the two wing control surfaces are deflected and about which there is no net normal force and moment.

7. A control system for a craft according to any of Claims 1 to 6 comprising means to manoeuvre comprising additional automated synchronized control deflection of both wings acting normal to the Zero Lift Line in the plane of manoeuvre under the action of a control routine.

8. A control system for a craft according to any of Claims 1 to 7 in which substantially all of a wing control surface is moveable under control actuation.

9. A control system for a craft according to any of Claims 1 to 8 comprising an additional flap portion of a moving wing control surface for control.

10. A control system for a craft according to any of Claims 1 to 9 wherein the craft is an aircraft, marine craft or UAV and wherein the control routine is operable to continually control both wing control surfaces to manoeuvre the craft for optimal fuel efficiency.

11. A control system for a craft according to any of Claims 1 to 10 wherein the craft is an aircraft, marine craft or UAV and wherein the control routine is operable to continually control both wings control surfaces to manoeuvre the craft to maintain optimal forward directional visibility.

12. A control system for a craft according to any of Claims 1 to 9 wherein the craft is a guided missile or torpedo in which the control routine is operable to continually position the manoeuvring main body at an angle

of incidence to the flight path velocity vector for optimal homing onto a target.

13. A control system for a craft according to any of Claims 1 to 9 where the craft is a guided missile or torpedo in which the control routine is operable to drive the manoeuvring main body axis to coincide with the flight path velocity vector to achieve zero angle of incidence (zero grazing incidence) at target impact for maximum warhead effectiveness.

14. A system according to any preceding claim wherein automated synchronised operation provides identical rotational and/or translational movement of the two wing control surfaces.

15. A system according to any preceding claim wherein automated synchronised operation provides proportional rotational and/or translational movement of the two wing control surfaces.

16. A system according to any preceding claim wherein automated synchronised operation provides geared rotational and/or translational movement of the two wing control surfaces.

17. A system according to any preceding claim wherein automated synchronised operation provides variable rotational and/or translational movement of the two wing control surfaces.

18. A system according to any preceding claim wherein the craft comprises more than two wing control surfaces.

19. A system according to any preceding claim wherein substantially all of a control surface is moveable under the automated synchronised operation.

20. A system according to any preceding claim wherein a flap portion of a wing control surface is moveable under the automated synchronised operation.

21. A system according to any of Claims 1 to 11 and 14 to 20 wherein the craft comprises an aircraft.

22. A system according to any of Claims 1 to 11 and 14 to 20 wherein the craft comprises a marine craft.

23. A system according to any of Claims 1 to 9 and 12 to 20 wherein the craft comprises a missile.

24. A system according to any of Claims 1 to 9 and 12 to 20 wherein the craft comprises a torpedo.

25. A system according to any preceding claim wherein the craft is unmanned.

26. A system according to any preceding claim comprising means to offset the body axis relative to the instantaneous flight path velocity vector.

27. A system according to any preceding claim comprising means to effect an applied manoeuvre about an instantaneous Zero Lift Line.

28. A system according to any preceding claim comprising means to maintain constant speed V.

29. A system according to any preceding claim comprising means to adjust, at an instant in time, the control surfaces setting to effect configuration of the Zero Lift Line and initiate manoeuvre relative to the Zero Lift Line in any plane of manoeuvre.

30. A system according to any preceding claim having a controller to provide, selectively as required:-

constant speed;

variable speed;

proportional rotation and/or translation movement of control surfaces under independent actuation;

geared rotational and/or translational movement of control surfaces under independent actuation;

variable rotational and/or translational movement of control surfaces under independent actuation.

31. A craft having a control system according to any one or more of Claims 1 to 30.

32. A method of controlling a craft having two wing control surfaces spaced apart along a main body section of the craft, the method comprising automated synchronized operation of the two wing control surfaces for continuous variable displacement in flight for manoeuvre of the main body relative to the flight path velocity vector with control to a predetermined angle of attack.

33. A control system according to Claim 1, comprising automated synchronized operation of the two wing control surfaces for continuous variable displacement in flight for manoeuvre of the main body relative to the flight path velocity vector with control to a predetermined angle of attack and attitude relationship.

34. A method of controlling a craft according to Claim 32 or 33 comprising automated synchronized operation of the two wing control surfaces to maintain continuous variable displacement of each wing via independent actuation under the action of a control routine.

35. A method of controlling a craft according to any of Claims 32 to 34 independent actuation of both wings under a control routine and involving operation of a soft actuation mechanism .

36. A method of controlling a craft according to any of Claims 32 to 35 comprising a demand manoeuvre acting along an axis normal to a Zero Lift Line and in the plane of manoeuvre is implemented.

37. A method of controlling a craft according to Claim 36 the Zero Lift Line is that line co-incident with the local wind axis velocity vector, acting in the plane of manoeuvre in which the two wings are deflected and about which there is no net normal force and moment.

38. A method of controlling a craft according to any of Claims 32 to 36 comprising additional automated synchronized control deflection of both wings acting normal to the Zero Lift Line in the plane of manoeuvre under the action of a control algorithm.

39. A method of controlling a craft according to any of Claims 32 to 38 comprising moving substantially all of a wing control surface under control actuation.

40. A method of controlling a craft according to any of Claims 32 to 39 comprising moving an additional flap portion of a wing control surface for control.

41. A method of controlling a craft according to any of Claims 32 to 40 wherein the craft is an aircraft, marine craft or UAV and comprising continually controlling both wing control surfaces to manoeuvre the craft for optimal fuel efficiency.

42. A method of controlling a craft according to any of Claims 32 to 40 wherein the craft is an aircraft, marine craft or UAV and comprising continually controlling both wing control surfaces to manoeuvre the craft for optimal forward directional visibility.

43. A method of controlling a craft according to any of Claims 32 to 40 wherein the craft is a guided missile or torpedo and comprising continually positioning the manoeuvring main body at an angle of incidence to the flight path velocity vector for optimal homing onto a target.

44. A method of controlling a craft according to any of Claims 32 to 40 wherein the craft is a guided missile or torpedo and comprising driving the manoeuvring main body axis to coincide with the flight path velocity vector for zero angle of incidence (zero grazing incidence) at target impact for maximum warhead effectiveness.

45. A method of controlling according to any of Claims 32 to 44 wherein automated synchronised operation provides identical rotational and/or translational movement of the two wing control surfaces.

46. A method of controlling according to any of Claims 32 to 45 comprising automated synchronised operation to provide proportional rotational and/or translational movement of the two wing control surfaces.

47. A method of controlling according to any of Claim 32 to 46 comprising automated synchronised operation to provide geared rotational and/or translational movement of the two wing control surfaces.

48. A method of controlling according to any of Claims 32 to 47 comprising automated synchronised operation to provide variable rotational and/or translational movement of the two wing control surfaces.

49. A method of controlling according to any of Claims 32 to 48 comprising moving more than two wing control surfaces.

50. A method of controlling according to any of Claims 32 to 49 comprising moving substantially all of a control surface moveable under the automated synchronised operation.

51. A method of controlling according to any of Claims 32 to 49 comprising moving a flap portion of a wing control surface under the automated synchronised operation.

52. A method of controlling according to any of Claims 32 to 42 and 45 to 51 wherein the craft comprises an aircraft.

53. A method of controlling according to any of Claims 32 to 42 and 45 to 51 wherein the craft comprises a marine craft.

54. A method of controlling according to any of Claims 32 to 40 and 43 to 51 or 52 wherein the craft comprises a missile.

55. A method of controlling according to any of Claims 32 to 40 and 43 to 51 or 53 wherein the craft comprises a torpedo.

56. A method of controlling according to any of Claims 32 to 55 wherein the craft is unmanned.

57. A method of controlling according to any of Claims 32 to 56 comprising off-setting the body axis relative to the instantaneous flight path velocity vector.

58. A method of controlling according to any of Claims 32 to 57 comprising effecting an applied manoeuvre about an instantaneous Zero Lift Line.

59. A method of controlling according to any of Claims 32 to 58 comprising maintaining constant speed V.

60. A method of controlling according to any of Claims 32 to 59 comprising adjusting, at an instant in time, the control surfaces setting to effect configuration of the Zero Lift Line and initiate manoeuvre relative to the Zero Lift Line in any plane of manoeuvre.

61. A method of controlling according to any of Claims 32 to 60 comprising operating a controller to provide, selectively as required:-

constant speed;

variable speed;

proportional rotation and/or translation movement of control surfaces under independent actuation;

geared rotational and/or translational movement of control surfaces under independent actuation;

variable rotational and/or translational movement of control surfaces under independent actuation.

62. A craft having a method of control according to any one or more of Claims 32 to 61.

63. A computer program product directly loadable into the internal memory of a digital computer, comprising software code portions for performing the method of any one or more of Claims 32 to 61 when said product is run on a computer.

64. A computer program directly loadable into the internal memory of a digital computer, comprising software code portions for performing the method of any one or more of Claims 32 to 61 when said program is run on a computer.

65. A carrier, which may comprise electronic signals, for a computer program of Claim 62.

66. Electronic distribution of a computer program product of Claim 63 or a computer program of Claim 64 or a carrier of Claim 65.